

The Potential for the Use of Grazing Management to Control Sediment and Phosphorus Losses in Runoff from Pastures

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TMDLs and Nonpoint Source Pollution

A section of the Clean Water Act of 1972 called for the development and implementation of Total Maximum Daily Loads, called TMDLs, to control nonpoint source pollution of surface water sources. Because of a concentration on the control of point source water pollution, relatively little implementation of TMDLs has been done. However, recent concerns with nonpoint source pollution have resulted in the use of TMDLs.

A TMDL is a written quantitative plan and analysis for attaining and maintaining water quality standards in all seasons for a specific water body and pollutant. A TMDL is required for every water body that appears on the 303(d) list of impaired water sources that is renewed every 4 years. In 2002, there were 158 water sources in Iowa on the impaired water source list; many of which listed because of sediment and nutrient pollution and their associated effects on drinking and recreational uses. Each of these water bodies must have a TMDL prepared within 10 years of appearing on the impaired waters list that must be implemented within 5 years and must achieve water quality standards within 10 years. While there are quantitative standards for toxic elements and chemicals, placement on the impaired water source list has often been based on the best judgment of natural resource professionals. However, the Environmental Protection Agency has mandated the use of quantitative standards for nutrients as well. Thus, there is the need for quantitative information regarding the activities within a watershed on nonpoint source pollution.

Phosphorus is considered the major nutrient problem in surface water sources in Iowa. Phosphorus pollution results in algae growth in surface water sources leading to increased turbidity, reduced dissolved oxygen, and loss of aquatic life. Because most Iowa soils contain phosphorus in quantities that are greater than adequate for crop production, the risk of phosphorus pollution of water sources is particularly great in Iowa. As a result, most water sources in Iowa contain phosphorus in concentrations greater than 100 to 200 micrograms per liter, which has been proposed as the upper limit for the phosphorus concentration in streams.

Most phosphorus in soil is adsorbed to soil particles. Thus, management practices that affect soil erosion likely also influence phosphorus pollution of surface water sources. The soil erosion rate from land planted in forages is at least 5 times less than crop planted in row crops and, therefore, forage

production should limit phosphorus as well as sediment losses in precipitation run-off. Conversely, a recent study has implied that watersheds which had a higher proportion of pasturelands contributed more sediment and phosphorus to pollution of a lake than did watersheds with less pastureland. This may be possible in overgrazed pastures at excessive stocking rates. However, it is known that well-managed rotational grazing will improve forage yields, plant vigor, and botanical composition of pasture, which may improve animal production. Furthermore, through rotational grazing, sward height and ground cover may be managed to maintain water infiltration and minimize erosion from pastures. Therefore, rotational grazing may provide the possibility of a win-win situation in which both animal production and water quality may be improved. To assess this possibility, there is the need to quantify the amounts of sediment and phosphorus that are lost in run-off from pastures grazed under different levels of management so that managed grazing may be included as an option in the development of TMDLs.

Therefore, a project is being conducted with the objectives, which include:

- To determine the effects of grazing with different stocking systems and residual heights on the amounts of sediment and phosphorus flowing in run-off from pastures with different slopes;
- To determine the effects of winter stockpiled grazing on the amounts of sediment and phosphorus flowing in run-off from pastures;
- To determine the effectiveness of buffer strips in controlling sediment and phosphorus flow in run-off from pastures;
- To develop and calibrate simple physical methods that can be used to monitor and manage sediment and phosphorus flowing in run-off from pastures; and
- To develop comprehensive nutrient balance plans to control nitrogen and phosphorus loss through appropriate management practices related to soil fertility, grazing, forage harvest, and animal nutrition.

Experimental Design

Three blocks of 6.8 acres were identified on hills with slopes up to 15° in a smooth brome grass pasture at the ISU Rhodes Research and Demonstration Farm near Rhodes, Iowa. Each block was subdivided into five 1-acre paddocks with an 18-ft wide lane at the top for cattle movement and a 30-ft wide buffer strip at the bottom. While soils within the paddocks were primarily Gara and Downs clay loams, soils within the buffer strips were primarily Colo and Ely. Because of the differences in soils, forage in the buffer strip was a combination of smooth brome grass and reed canarygrass. Prior to initiation of grazing, pastures were fertilized with phosphorus to an adequate level, based on soil analysis, and urea was applied at 180 lb/ac. Sandbags were placed around the perimeter of each paddock to prevent cross-contamination of run-off.

Five forage treatments were assigned to paddocks within each block. Treatments included: an ungrazed control, summer hay harvest with winter stockpiled grazing, continuous stocking during summer to a residual sward height of 2 in., rotational stocking during summer to a residual sward height of 2 in, and rotational stocking during summer to a residual sward height of 4 inches.

Grazing was initiated in May with 3 cows per 1-acre paddock. In the continuous stocking systems, cattle were removed from the paddocks after sward height decreased to 2 in. To simulate continuous stocking, these paddocks were only allowed rest periods of only 7 to 10 days, which limited regrowth. In the rotational stocking systems, cattle were removed from paddocks after the sward height decreased to 2 to 4 in. Paddocks were allowed 35-day rest periods for regrowth. Forage sward heights were measured twice weekly during the grazing season to determine when cattle should be removed. Forage was harvested as first-cutting hay in June and clipped in early August from the paddocks in the hay/stockpiled grazing system. Each paddock in the hay/stockpiled grazing system was stocked with 2 cows in mid-November and grazed to a residual sward height of 2 in. Mean carrying capacities of paddocks with the ungrazed, hay/stockpiled grazing, 2 in. continuous stocking, 2 in. rotational stocking, and 4 in. rotational stocking systems were 0, 19, 199, 146, and 111 cow-days/ac in year 1.

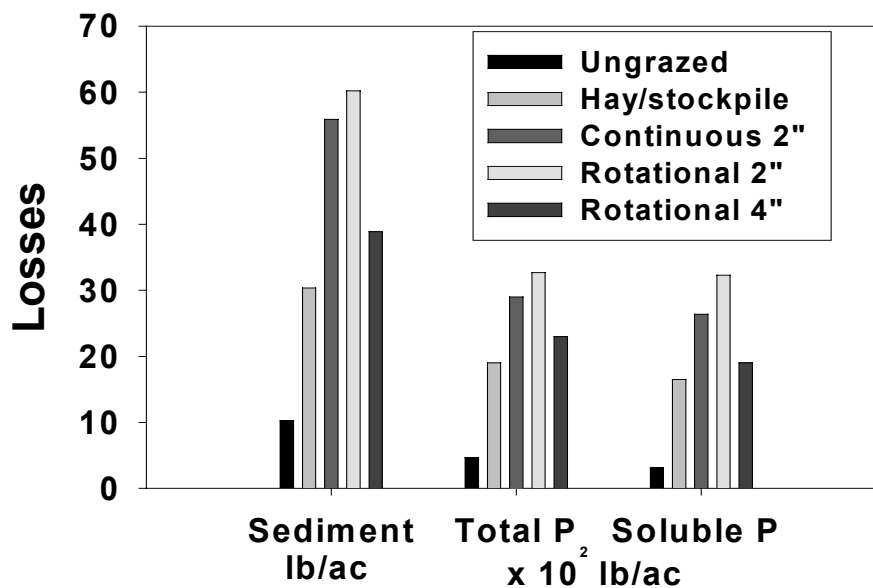
To determine the effects of forage treatment on sediment and phosphorus loss, rainfall simulations at a rate of 2.8 in./hour were conducted at twelve locations within two slope classes within each paddock, three locations at the base of each paddock and three locations 30 ft. within the buffer strip beneath each paddock. Furthermore, run-off from natural rainfall was collected from plots with no buffer strip and grazed to buffer strip areas of 5:1 and 10:1 from paddocks with the ungrazed, 2-in. continuous stocking, and 2-rotational stocking treatments. In order to identify physical measurements that might be used to estimate sediment and phosphorus loss, soil composition, surface roughness, and penetration resistance and sward height, cover and mass were determined and related to sediment and phosphorus losses.

Preliminary Results

In the first year of the experiment, annual losses of sediment and total phosphorus were greater from paddocks in which forage was harvested either as hay or pasture in the ungrazed paddocks (Figure 1). However, losses of sediment and total phosphorus from paddocks with the hay/stockpiled grazing and 4-in. rotational stocking treatments were one-half those of paddocks grazed to 2 in. either by continuous or rotational stocking. Soluble phosphorus loss from paddocks grazed to a residual height of 2 in. by continuous or rotational stocking were nearly 10 times greater than ungrazed paddocks. However, soluble phosphorus losses from paddocks in the hay/stockpiled grazing and 4 in. rotational stocking systems were 40% less than paddocks grazed to 2 in. residual

sward height. Surprisingly, there were no differences in the sediment, total phosphorus, and soluble phosphorus losses between the two slope classes in the paddocks. Mean total phosphorus losses were 76% less and soluble phosphorus losses were 77% less within the buffer immediately at the base of each paddock and 30 ft. within the buffer strip than in the paddocks, but there were no differences in phosphorus losses from the two locations with the buffer strip. This implies that relatively narrow buffer strips might be adequate to control sediment and phosphorus losses. At present, only June data from the second year have been analyzed from the rainfall simulations. Similar to the first year, total phosphorus losses from pastures grazed by continuous stocking were 17 times greater than ungrazed paddocks. However, paddocks harvested for hay in the hay/stockpiled

Figure 1. Sediment and Phosphorus losses from paddocks with different forage management practices



grazing system or grazed to 2 or 4 in. either by rotational stocking did not differ from ungrazed paddocks. Similarly, soluble phosphorus losses did not differ between paddocks in any treatments. As in the first year, total and soluble phosphorus losses were 67 and 83% lower from buffer strips than paddocks.

To support the validity of the rainfall simulation data, run-off from natural rainfall events in paddocks that were ungrazed or grazed to 2 in. by continuous or rotational stocking was collected and analyzed. In a 2.8 in. rainfall in September of the first year, total sediment losses were greater in the continuously stocked

paddocks than the ungrazed or rotational stocked paddocks. In addition, total and soluble phosphorus losses from ungrazed paddocks were less than continuously stocked paddocks, but did not differ from the rotationally stocked paddocks. Similarly, total and soluble phosphorus losses from continuously stocked paddocks were greater than the ungrazed or rotationally stocked paddocks after a 1.7 in. rainfall in the second year. In the first year, there were no differences in sediment or phosphorus losses in plots with or without buffer strips. However, total and soluble phosphorus losses during a 1.7 in. rainfall in the second year were lower in plots with a 5:1 or 10:1 pasture to buffer area ratio than plots with no buffer.

Forage harvest by haying or grazing with continuous or rotational stocking increased penetration resistance in the upper 4 in. of soil by August of year 1 and at the 4 to 8 in. depth by April of the subsequent year. In June of year 2, penetration resistance in the upper 4 in. of soil were greater in paddocks grazed either by continuous or rotational stocking than paddocks that were ungrazed or harvested as hay. However, surface roughness did not differ between treatments. Forage sward heights in hayed or grazed paddocks were 50% less than the ungrazed paddocks by June of year 1, but did not differ between other treatments. In August, October, and April of year 1, sward heights of paddocks grazed by continuous stocking to 2 in. were 45 to 68% lower than the ungrazed paddocks. There were no differences in forage sward heights of paddocks in the hay/stockpiled grazing, 2 in. rotational stocking or 4 in. rotational stocking systems in August and October of year 1, but were lower 3 to 53% less than the ungrazed paddocks in these months. Forage sward heights of paddocks that were harvested for hay and grazed as stockpiled forage or grazed by rotational stocking to 4 in. did not differ from ungrazed paddocks in April of year 1. Similar to sward height, forage masses of paddocks in which forage was harvested by haying or grazing were 53, 68, 45, and 50% lower than the ungrazed paddocks in June, August, October, and April of the first year. But forage masses in paddocks in the hay/stockpiled grazing and the rotational stocking to 2 or 4 in. systems were 49 and 88% greater than paddocks grazed by continuous stocking to 2 in. Forage canopy covers were lower in paddocks with forage harvested by haying or grazing than ungrazed paddocks and in paddocks continuously stocked to 2 in. than paddocks with the hay/stockpiled grazing or rotational stocking treatments.

Total and soluble phosphorus losses were higher from soils with higher concentrations of plant available phosphorus. Therefore, measures that reduce phosphorus loss are particularly important on soils with high phosphorus contents. Of the physical measurements taken, sediment and total phosphorus losses were most highly related to ground canopy cover. Therefore, controlling canopy cover through practices such as forage species selection and rotational grazing may be used to limit sediment and phosphorus pollution of surface water sources.

Conclusions

From preliminary data, it seems that forage harvest either by hay harvest or grazing is associated with greater losses of sediment and phosphorus than not harvesting. On the other hand, because of the relationship of ground cover with sediment and phosphorus loss, presumably these losses would be lower in land planted in forage and harvested by any method than from land planted in row crops. Furthermore, the reductions in sediment and phosphorus loss from paddocks harvested for hay and grazed in winter as stockpiled forage or grazed by rotational stocking to a height of 4 in. imply that while harvest management may not totally eliminate sediment and phosphorus losses, it may be used to reduce these levels to acceptable levels. Rotational grazing by itself did not seem to control sediment and phosphorus if both done to the same residual sward height in the first year. The lower phosphorus losses from the 2 in. rotational stocking treatment in June of the second year may imply that in the long-term this treatment may prove to be more effective than continuous stocking to 2 in. Not surprisingly, forage buffer strips have been very effective at limiting sediment and phosphorus losses from pastures even if they are relatively narrow.

Thus, pasture management and buffer strips do provide tools that might be used to limit sediment and phosphorus pollution of surface waters. However, because the effects of these treatments on plant vigor and soil properties are likely to be additive over time, this research needs to be carried on for a number of years. Furthermore, economic analyses are needed to determine what combinations of practices would optimize environmental protection while also being economically acceptable.

Rotational stocking has its positive effects of forage growth and nutritional quality and, hence, sediment and phosphorus loss through alteration of the animals' behavior so that animal activities like grazing, resting and excretion are more uniformly distributed across the pasture. While this project seems to demonstrate the potential for rotational stocking managed to specific minimum sward heights to reduce sediment and phosphorus pollution, further research is needed on measuring the effects of additional management practices of altering animal behavior to reduce concentration of cattle within riparian areas. Such practices might include the placement of mineral supplements, shade or alternate water. Furthermore, the effects of approaches of stabilizing streams at points of animal access on animal behavior and water quality need measurement.

While the preliminary results of this project imply that pasture management does provide the opportunity to improve surface water quality, the effects of all activities within a watershed on water quality must be considered. Thus, approaches that integrate management of all activities within a watershed are needed to develop effective plans to control nonpoint source pollution.